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Feasibility study of developing photovoltaic power projects in Italy: An integrated approach

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ABSTRACT

The balance between the demand for electricity by consumers and businesses, and environmental protection, is one of the key challenges of our society.

The PV industry in 2010 compared to 2009 registered a growth of 130%, consolidating the previous achievements. The reduction in costs of system and incentive policies have favored the development of solar energy.

At the same time, the results achieved have led to a resulting reduction of Feed-in Tariff (FiT) by the central governments, generating concern from both the owners, investors and operators.

This article belongs to a wider research and aims to analyze the determinants of investment risk in the PV industry through a sensitivity analysis, scenario analysis and risk analysis. To do this, alternative business plans have been developed that compared to the static situation, allow to quantify how Net Present Value varies according to different parameters. Strong attention is placed on the project's critical variables, the opportunity cost of capital, the time duration of the project, the plant size and geographical location of the system, analyzing the specific case of Italy.

Contents

1. Introduction

In 2010, the European Union was the world's largest PV market. More than 13 GW are been installed in 2010 and the total installed PV capacity is erased from 16 to almost 30 GW. Germany represents more than 50% with 7.408 MW installed in 2010, the second country is Italy (2.321 MW) and third Czech Republic (1.490 MW). It is to underline also the rapid grow of France in 2010 that has installed 719 MW. The Spanish market has recovered the negative situation of 2009, installing 369 MW in 2010. Also for the medium-sized markets there is to underline a positive trend: Belgium 424 MW, Greece 150 MW, Slovakia 145 MW. The United Kingdom is one of the most promising EU market in short term.

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Table 1
World cumulative PV power 2010 installed in main geographies.

Country	Country PV installed (MW)	% PV installed
Germany	7.408	55,9%
Italy	2.321	17,5%
Czech Republic	1.490	11,2%
France	719	5,4%
Belgium	424	3,2%
Spain	369	2,8%
Greece	150	1,1%
Slovakia	145	1,1%
Rest of EU	98	0,7%
Austria	50	0,4%
United Kingdom	45	0,3%
Portugal	16	0,1%
Bulgaria	11	0,1%
Total	13.246	

84% of the total PV MW installed

The 2010 PV market in Germany overshadows other European market, only Italy is in the same level (Table 1).

The SET for 2020 Report, released by EPIA, identifies three possible PV deployment scenarios that represent the real potential of technology. The baseline scenario envisages a business as usual case with a 4% of the electricity demand in the EU provided by PV in 2020. In this scenario, PV penetration in 10 countries is expected to reach approximately 100 GW out of a total of 130 GW in the total of Europe (Fig. 1).

Different national governments, as a result of the Kyoto agreements, have adopted different support elements for support PV deployment to compensate for the disadvantages of higher costs. They have to act to de-bottleneck administrative procedures and ensure sustainable levels of temporary financial support by means of well-designed FiT to ensure continuous PV deployment. PV energy can not only help to meet the 20/20/20 goals, it is also useful in line with the broader policy objectives of strengthening the competitiveness of Europe's industry and enhancing energy security, while bringing power to society as a truly decentralized form of renewable energy [1,2].

Different support elements can be used for PV systems, according the Epia study, it is possible to compare the PV support, in Table 2 the overall impact of all available support systems is presented. FiT complemented by the availability of soft loans has been highly effective and the adoption of FiT in Germany and in Italy has effectively fostered faster market growth. Therefore, the absence of FiT for PV systems as in Romania and UK is a negative characteristics of the national PV support landscape of these countries.

Among the positive aspects related to solar energy are to remember [3]:

- Environmental benefits including the 20/20/20 objectives: PV can help to fill the gap to reach the EU's 2020 renewable energy target, PV directly reduces the rising CO_2 emissions from power generation, and, will do so in an environmentally friendly way with full life cycle responsibility for the product.
- Economic benefits: PV investment provides a positive NPV, increases the long-term energy security of supply, provides valuable peak power, enables reduction of network losses, contributes to technology leadership and job creation.

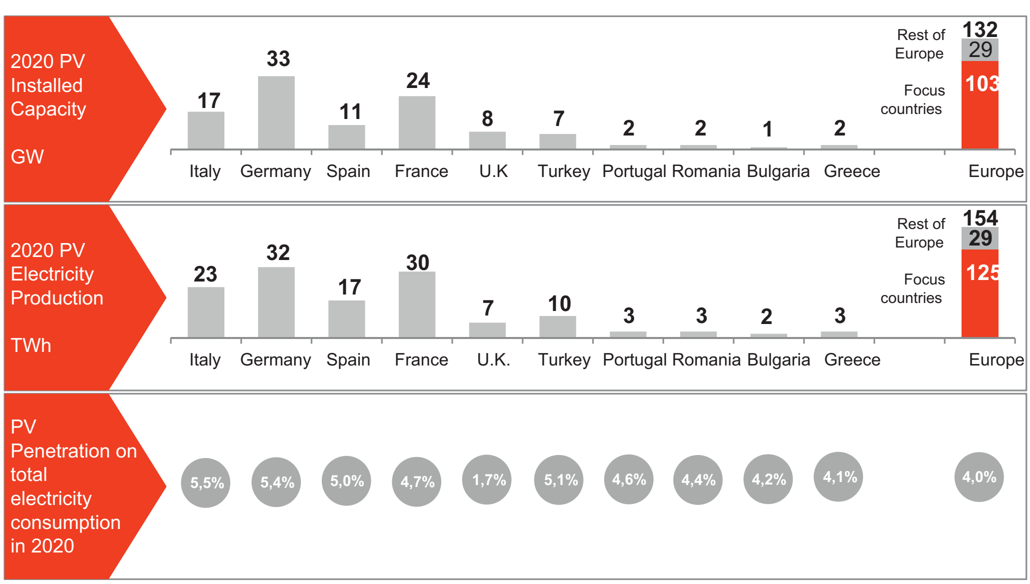


Fig. 1. PV penetration in 10 focus countries.

Table 2
PV policy status by country.

	Legend		IT	ES	DE	PT	FR	GR	TR	RO	BG	UK
Appropriateness of PV support		FINANCIAL SUPPORT SYSTEMS										
		Feed-in Tariff	♣	©	♣	©	♣	©	♣	ξ	©	ξ
		Investment Grants	ξ	ξ	ξ	©	©	©	ξ	©	©	©
	Well designed ♣	Beneficial Credit Terms	ξ	ξ	♣	©	ξ	©	ξ	ξ	♣	ξ
	Design to be improved ©	Tax Credit	©	ξ	©	©	©	©	ξ	ξ	ξ	©
	Non-existing ξ	Quota/TGC*	ξ	ξ	ξ	ξ	ξ	ξ	ξ	♣	ξ	♣
		Net Metering	ξ	ξ	©	ξ	ξ	ξ	ξ	ξ	ξ	ξ
		Existence of CAP for emission check	©	ξ	♣	ξ	©	♣	♣	ξ	♣	ξ
		LEVEL OF FIN. SUPPORT AVAILABLE (IRR)										
		Residential System	♣ ©	♣ ©	♣	♣	ξ ♣	♣ ©	ξ	ξ	©	ξ
	Sustainable IRR♣	Commercial Building Adapted PV	♣ ©	♣	ξ ♣	ξ	ξ ♣	©	ξ	ξ	♣	ξ
	Risk of overheating ©	Commercial Building Integrated PV	♣ ©	ξ ♣	ξ ♣	ξ	♣ ©	©	ξ	ξ	♣	ξ
	IRR too low ξ	Industrial Rooftop	♣ ©	♣ ©	ξ ♣	ξ	ξ ♣	©	ξ	ξ	♣	ξ
		Industrial Ground-mounted	♣ ©	♣ ©	ξ	ξ	ξ ♣	©	ξ	ξ ♣	♣ ©	ξ
Ease of Installation Procedures		ADMINISTRATIVE COMPLEXITY										
		Authorisation Procedures	©	©	♣	♣	ξ	ξ	ξ	ξ	©	♣
	Work well, favourable ♣	AdministrativeLead Time	©	ξ	©	♣	©	♣	ξ	♣	♣	♣
	Could be improved ©	GRID CONNECTION COMPLEXITY										
	Not sufficinet ξ	Grid Connection Cost Division	ξ	♣	♣	ξ	♣	ξ	ξ	ξ	♣	♣
		Grid connection lead time (months)	♣	♣	♣	♣	ξ	♣	ξ	♣	♣	♣
Industry Significance and Influence	Significant/Strong ♣											
	Intermediate ©	Significance of Industry Base	♣	♣	♣	ξ	©	©	ξ	ξ	ξ	ξ
	Not significant/existing ξ	Strength of National Association	©	♣	♣	©	♣	©	©	ξ	©	©

Italy (IT), Spain (ES), Germany (DE), Portugal (PT), France (FR), Greece (GR), Turkey (TR), Romania (RO), Bulgaria (BG), United Kingdom (UK).

- Social benefits: PV contributes to electrification of rural, under-supplied areas, provides a cap to increasing household energy cost.

The negative aspects are, however, linked to poor concentration per unit area and the non-programmability, being the radiation not constant due to weather changes and seasonality [4,5].

The future perspective shows that the development of photovoltaic industry chain leads to the market can become more mature and reference this issue pushes national governments to reduce the incentive policies [6]. To address the concerns of owners and/or investors it is necessary to delaine alternative scenarios to those in a static situation, in order to assess how the individual variables can influence the viability of such systems. This paper is framed within a broader analysis in which it is analyzed the geographical Italian situation, gained results showed very different realities in the country [7]. The plants located in the south, due to highest insulation hours, have higher financial return than what occurs in the central area and even more than the north.

In the previous analysis, based on local characteristics of location plant, has been defined, with a regional focus, the number of photovoltaic systems necessary to satisfy the demand for energy. The supply of energy has been calibrated on the basis of some parameters such as mean annual insolation, the amount consumed by the user level and the design criterion used [8].

The article is organized into the following steps: in Section 2 the Italian programs in PV sector are presented. In Section 3 a sensitivity analysis is offered that aimed at identifying the critical variables and to assess its impact on economic and financial indices. A variable is considered to be critical when an its variation (positive or negative) of 1% determines a corresponding variation of 5% of the NPV. Optimistic and pessimistic scenarios are identified, where the critical variables vary independently. An aspect of sensitivity analysis is the margin of safety which is the amount of budgeted revenue over and above breakeven revenue. For the critical variables the switching value is identified. The switching value of a variable is that value that would have to occur in order for the NPV of the project to become zero, or more generally, for the outcome of the project to fall below the minimum level of acceptability.

The use of switching values in sensitivity analysis allows appraisers to make some judgments on the riskiness of the

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Annual installed PV power	3,6	2,0	1,7	0,2	0,7	1,0	0,8	0,5	1,0	2,0	4,0	4,7	6,8	12,5	70,2	338,1	723,0
Previous cumulative installed PV power	8,5	12,1	14,1	15,8	16,0	16,7	17,7	18,5	19,0	20,0	22,0	26,0	30,7	37,5	50,0	120,2	458,3
Cumulative installed PV power	12,1	14,1	15,8	16,0	16,7	17,7	18,5	19,0	20,0	22,0	26,0	30,7	37,5	50,0	120,2	458,3	1.181,3

Fig. 2. Annual and cumulative installed PV power (MW) in Italy: historical perspective.

project and the opportunity of undertaking risk-preventing actions.

Moreover are investigated the relationships between performances indicator and opportunity cost of capital and time duration of the project.

In the preliminary analysis developed in Section 4 are identified regions in which the profitability PV investments is higher, these regions have a greater ability to support a general worsening of conditions in which the investment is implemented. In Section 5 are analyzed the variables that can justify the higher profitability. The geographical location, although it is usually an important aspect in every country, is even more marked in Italy for the particular conformation of the territory.

After the sensitivity analysis, Section 6 discusses a scenario analysis, in which optimistic or pessimistic scenario is defined by extreme values of the probability distribution. In this article more optimistic and pessimistic scenarios are examined, each scenario presents the percentage differences of the variables with respect to the baseline scenario.

In Section 7, however, has made a risk analysis in which the critical variables are described trough proper probability distribution, this allows to estimate interesting statistics performance indicators of the project, as the expected values, the cumulative probability of positive NPV and the cumulative probability.

The results to be presented referring to costs, incentives and electricity yields are all normalized per kWp, in order to assess the impact of plant size on the profitability of investment in each region, in Section 8 are made to vary the supply and demand of electricity, acting respectively on the number of photovoltaic modules and the value of the energy required by the user in the first year of system life.

The conclusions (Section 9) allow to summarize the results obtained.

2. A focus on Italian photovoltaic program: background and future

The PV industry experienced significant growth in 2010. Capacity additions grew from 7.2 GW installed in 2009 to 16.6 GW in 2010. The total installed capacity in the world now amounts to around 40 GW, producing some 50 terawatt-hours (TWh) of electrical power every year.

This major increase was linked to the rapid growth of the German and Italian markets.

For a couple of years, the PV market growth has been driven by rapid decrease in prices accelerated by support schemes. In Italy, despite difficult economic conditions, there was growth of the annual PV market (i.e. the amount of PV installed during calendar year 2009) between 2008 and 2009 (Fig. 2).

The government deployment activities have a relevant role in the PV implementation. Besides high sun irradiation, Italy offers a very attractive support scheme, mixing net-metering and a well segmented FiT. In January 2009, the Italian government extended the net-metering to PV systems up to 200 kW. This means the PV system owner can value the electricity he produces himself at the same price as the electricity he consumes traditionally from the grid. If, over a time period, there is an excess of electricity fed into the grid, the PV system owner gets a credit (unlimited in time) for the value of the excess of electricity. This measure can be considered as quite attractive for the residential, public and commercial sectors.

In 2009, 723 MW of PV power were installed in Italy, more than twice the size of the market in 2008 and second in magnitude behind only the German market. Cumulative installed PV power reached almost 1.2 GW. The grid-connected centralized PV power systems market is growing particularly rapidly and now accounts for 43% (up from 33%) of the total installed capacity; grid-connected distributed PV systems now account for 56% of the total installed capacity.

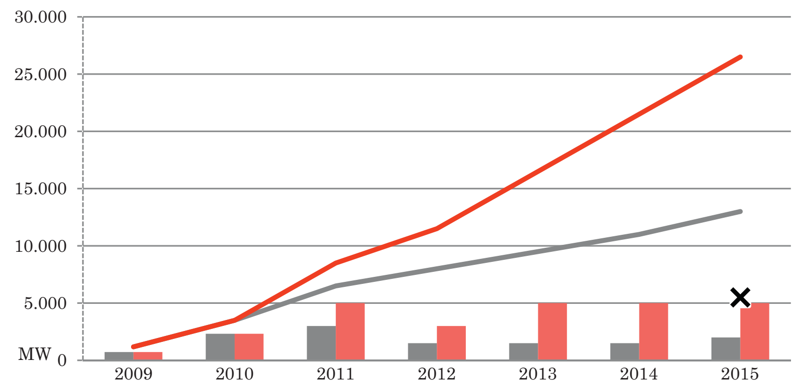
Off-grid PV applications continue to decrease in relative importance. Interestingly, while off-grid non-domestic applications are slowly increasing in number, the total installed power for off-grid domestic systems is decreasing because of decommissioning of systems installed in the early 1980s.

The national market stimulation initiative in operation during 2009 is the Conto Energia Programme. The first stage, Primo Conto Energia, was completed toward the end of 2009 with 5.733 PV plant installations. The second stage, Nuovo Conto Energia, was defined by governmental decree in February 2007 and together both stages have resulted in 71.284 PV plants.

The rapid market growth seen in 2008 and 2009 was driven by the changes to the FiT decree which were adopted in early 2007.

The Italian government has finally approved the third Energy Bill (Conto Energia) which will reduce the tariffs in multiple phases. The government hopes it will not put the development of PV at risk in Italy.

The evolution of PV Italian sector, can be analyzed though the data elaborated by EPIA [9] among a highly representative sample



	2009	2010	2011	2012	2013	2014	2015
EPIA Moderate	723	2.321	3.000	1.500	1.500	1.500	2.000
EPIA Policy-Driven	723	2.321	5.000	3.000	5.000	5.000	5.000
EPIA Moderate (cumulative)	1.181	3.494	6.500	8.000	9.500	11.000	13.000
EPIA Policy-Driven (culumative)	1.181	3.494	8.500	11.500	16.500	21.500	26.500
✖ National Target 2015							5.500

Fig. 3. Italian future scenario.

of the PV industry, electric utilities, national associations and energy agencies. EPIA has derived two scenarios (The Moderate and Policy-Driven scenario) for the future development of the PV industry. Under these two scenarios, can be analyzed the Italian evolution.

According to the latest market development in the country, EPIA expects the market to reach 1.5 GW and even possibly up to 2 GW. EPIA retains 1.5 GW as its Policy-Driven target for 2010 (up from 1.2 GW in its previous estimate) at the time of closing that publication. In EPIA's Policy Driven scenario, the market could grow to up to 2 GW in 2014 (Fig. 3).

The market has been estimated to reach as high as 6 GW of installations. As of end 2010, however, only 2.3 GW had been effectively connected to the grid.

In 2011, the total amount of installations is expected to range from 3 to 5 GW.

The government's decision to maintain registration under the current Conto Energia program open until June 2011 (for installations that have not yet been connected but were installed before the end of 2010) indicates the strong political commitment to safeguard investor's confidence in PV.

The data report for a PV system can be delayed by a couple of months before being taken into consideration by the regulator and published. A large part of the 2009 PV market was only registered during the 3 first months of 2010, making the market outlook in Italy less straightforward to estimate [10,11].

3. Sensitivity analysis

The present paper is based on the results gained in a more deeper analysis where are ben defined the profitability of several PV systems located on all the Italian regions. These results are the starting point of some analysis where the role of parameters for photovoltaic systems is investigated. Since the planning process involve variables, these parameters should be varied and different scenarios should be projected [12]. For the aim of the present paper, the results presented referring to costs, incentives and electricity yields that are normalized per kWp. Based on normalized input, the NPV of each PV system is been estimated. NPV is emphasized since this profitability index is probably one of the most meaningful for investors (Table 3).

Given the uncertainty that is involved to parameters of these projects, sensitivity analysis is useful to analyze the impact that costs and benefits variables have on financial and economic indices. Sensitivity analysis is a measure utilized for the assessment of risk involved in the project. It assesses the impact of different variables on the returns of an investment. It is utilized for the assessment of the impact of the changes in the critical variables, on the project profitability [13]. Alternatively scenario analysis is a measure that utilized for the evaluation of the combined effect of different variables (scenarios). Since the variables involved in this investment are interrelated, there are alters in combination. Both the techniques assist in evaluating the risk associated with the investment. Sensitivity analysis is useful for the evaluation of the investment on a project. The effect of different variables on the cost benefit ratio, that is NPV or IRR, can be effectively evaluated with the assistance of sensitivity analysis. The estimates for each variable are calculated on the basis of two different states of the future value, which are pessimistic and optimistic.

Scenario analysis considers that the variables involved in the estimation of cost benefit ratio are interrelated. Therefore, for the different scenarios, NPV is evaluated by taking the pessimistic, optimistic values of the variables. The results for each scenario are compared and the most reliable scenario is considered and then the investment is done accordingly [14].

Table 3
Base scenario: kWp normalized plant.

	NPV
Sicily	2.569
Sardinia	2.357
Calabria	2.355
Apulia	2.213
Basilicata	2.144
Campania	2.137
Lazio	2.049
Molise	2.018
Abruzzo	1.914
Umbria	1.890
Marche	1.837
Media	1.839
Tuscany	1.818
Liguria	1.732
Emilia Romagna	1.719
Veneto	1.539
Piedmont	1.525
Lombardy	1.483
Friuli	1.286
Trentino	1.152
Aosta Valley	1.047
National average	1.839

Table 4
Sensitivity analysis—critical variables identification.

	Independent variables										
	FiT_{ben}	SC_{el}	SP_{el}	S	inf_{el}	inf	C_m	C_{ass}	FS_r	r	I_0
Piedmont	3.58%	1.83%	0.03%	0.09%	0.33%	0.11%	0.07%	0.22%	0.08%	0.64%	4.54%
Aosta Valley	4.90%	2.56%	0.01%	0.14%	0.45%	0.16%	0.10%	0.33%	0.03%	0.93%	6.61%
Lombardy	3.66%	1.88%	0.03%	0.10%	0.34%	0.11%	0.07%	0.23%	0.07%	0.66%	4.67%
Trentino	4.51%	2.35%	0.02%	0.12%	0.41%	0.14%	0.09%	0.30%	0.04%	0.85%	6.00%
Veneto	3.55%	1.82%	0.03%	0.09%	0.33%	0.11%	0.07%	0.22%	0.08%	0.63%	4.50%
Friuli	4.11%	2.13%	0.02%	0.11%	0.38%	0.13%	0.08%	0.27%	0.06%	0.76%	5.38%
Liguria	3.23%	1.64%	0.04%	0.08%	0.30%	0.10%	0.06%	0.20%	0.10%	0.56%	4.00%
Emilia R.	3.25%	1.65%	0.04%	0.08%	0.30%	0.10%	0.06%	0.20%	0.10%	0.57%	4.03%
Tuscany	3.11%	1.57%	0.05%	0.08%	0.29%	0.09%	0.06%	0.19%	0.11%	0.54%	3.81%
Umbria	3.02%	1.51%	0.05%	0.08%	0.28%	0.09%	0.05%	0.18%	0.12%	0.52%	3.66%
Marche	3.09%	1.55%	0.05%	0.08%	0.28%	0.09%	0.05%	0.19%	0.11%	0.53%	3.77%
Lazio	2.84%	1.41%	0.06%	0.07%	0.26%	0.08%	0.05%	0.17%	0.13%	0.48%	3.38%
Abruzzo	2.99%	1.50%	0.05%	0.07%	0.28%	0.09%	0.05%	0.18%	0.12%	0.51%	3.61%
Molise	2.88%	1.42%	0.06%	0.07%	0.26%	0.08%	0.05%	0.17%	0.13%	0.48%	3.43%
Campania	2.76%	1.35%	0.06%	0.07%	0.25%	0.08%	0.05%	0.16%	0.14%	0.46%	3.24%
Apulia	2.69%	1.31%	0.07%	0.06%	0.25%	0.08%	0.05%	0.15%	0.15%	0.44%	3.13%
Basilicata	2.75%	1.35%	0.06%	0.07%	0.25%	0.08%	0.05%	0.16%	0.14%	0.45%	3.23%
Calabria	2.57%	1.23%	0.07%	0.06%	0.23%	0.07%	0.04%	0.15%	0.17%	0.41%	2.94%
Sicily	2.42%	1.13%	0.09%	0.06%	0.22%	0.06%	0.04%	0.13%	0.19%	0.38%	2.69%
Sardinia	2.57%	1.23%	0.07%	0.06%	0.23%	0.07%	0.04%	0.15%	0.17%	0.41%	2.94%
Average	3.22%	1.62%	0.05%	0.08%	0.30%	0.10%	0.06%	0.20%	0.11%	0.56%	3.98%

Acronyms of variables: FiT_{ben}: Feed in Tariff benefit (+1%); SC_{el}: self consumption eletrical power (+1%); SP_{el}: selling price of electricity (+1%); S: salvage value (+1%); inf_{el}: energy inflation rate (+1%); inf: inflation rate (−1%); C_m: maintenance cost (−1%); C_{ass}: assurance cost (−1%); FS_r: Fiscal rate (−1%); r_L: loan interest rate (−1%); I_0: initial investment cost (−1%).

A criterion for defining the critical variables is to identify those variables that produce a change in the output larger than the change in the variable itself (in the case of percent changes in the variables). For PV sector, a variable is critical if for a 1% change there is 5% change in the NPV (European Commission [15]).

The procedure that should be followed to conduct a sensitivity analysis includes the following steps:

- Identification of the variables used to calculate the output and input of the financial and economic analyses, grouping them together in homogeneous categories.
- Deterministically dependent variables would give rise to distortions in the results and double counting. It is necessary to eliminate the redundant variables, choosing the most significant ones, or to modify the model to eliminate internal dependencies. The variables considered must, as far as possible, be independent variables. Additionally, variables should, as far as possible, be analyzed in their disaggregated form. It is advisable to carry out a preliminary qualitative analysis of the impact of the variables in order to select those that have little or marginal elasticity. The subsequent quantitative analysis can be limited to the more significant variables.
- At the end of this selection, the critical variables will presumably be few, unless the threshold value chosen for performance elasticity is exaggeratedly small.
- Define the critical variables according the selected criterion.

The sensitivity analysis allow also to identify the margin of safety which is the variation percentage amount of variables that it is possible to support before that the NPV become zero.

3.1. NPV and change in critical variables

This work belongs to a larger research and aims to assess the impact of some variables (that determine PV investment costs and benefits) on the investments profitability. Particularly, starting from the constraints imposed by the Kyoto Protocol, has been defined the number of photovoltaic systems to be installed throughout the country to achieve the dual aspect: meet the national demand for energy and respect the limits of CO_2 emissions. The analysis has been performed with a regional detail, and for each region has been quantified (by estimating the NPV) the profitability of these investments [7].

The profitability of these investments is determined by the following variables: Feed in Tariff benefits (FiT_{ben}), self consumption electrical power (SC_{el}), selling price of electricity (SP_{el}), salvage value (S), inflation rate of energy (inf_{el}), inflation rate (inf), maintenance cost (C_m), assurance cost (C_{ass}), fiscal rate (FS_r), loan interest rate (r_L), initial investment cost (I_0).

These variables are all independent, given their small number it is not necessary to perform the qualitative analysis. For quantitative analysis, it is evaluated a positive or negative 1% variation for each variable. The new values recorded in the NPV due to the variation of each variable are presented in Table 4.

Theoretically, can be classified as critical the variables that determine a variation in NPV greater than 5%, in fact, on average national level none of the variables examined has an impact of this measure. Analyzing, however, regional data for 3 regions (Aosta Valley, Trentino, Friuli) the variable I_0 has an impact of more than 5% on the NPV.

The low influence of variables on NPV is indeed influenced by the size of the PV system fixed, the data to be presented referring to costs, incentives and electricity yields are all normalized per kWp. The PV system for domestic use, really have an higher capacity and analyzing different case studies it is possible to define that the critical variables of a photovoltaic system for small and medium size are: Feed in Tariff benefit (FiT_{ben}) and in Initial investment cost (I_0), which respectively represent the largest component of income and cost [16,17].

Are also considered as critical the two macro-variables related to the Embodied energy of the PV module fabrication (E_f) and the electric energy required by consumers (Q_{el}) [18]. In this way, it is possible to define optimistic and pessimistic scenarios (Table 5) by varying the 4 critical variables in 5 subscenarios, in which the variables increase or decrease of 5%.

Since these PV systems are designed to meet the financial needs and electricity supply of a medium user, the index used for investments valuation is the NPV, which has the advantage of immediate

Table 5
Assumptions on critical variables behavior for optimistic and pessimistic scenarios.

Scenario	FiT_{ben}	I_0	E_f	Q_{el}
Optimistic	↑	↓	↑	↑
Pessimistic	↓	↑	↓	↓

and easy to understand. So, have been ignored indexes for estimate the percentage of return (IRR) or results in financial terms and non-economic (cost–benefit ratio discounted).

Analyses were performed for all regions, due to the analyses extension and for space reasons, for illustrate the analysis performed, are presented the results obtained for two regions, a Southern Region (Sicily, Table 6) and one in northern Italy (Lombardy, Table 7). In these tables are defined:

- $\Delta V\%$ = percentage variation of variable;
- x_i = Net Present Value in scenario i;
- x^* = Net Present Value in base scenario. In Sicily is 2.569 € and in Lombardy is 1.483 €.

Analyzing the results obtained for all Italian regions, it is possible to underline some conclusions on the relationship between the NPV and the critical variables:

- the relationship between FiT tariff and NPV is linear and symmetrical regardless the plant location; this is an expected result because the FiT tariff is equal to a constant value for a period of 20 years and for a given size PV system and being the NPV determined by the product of that value and the energy produced by PV systems. A decrease of 17% of lost funds in Sicily have the same impact that is recorded in the baseline scenario in Lombardy, a positive variation of 20% of the same variable in Lombardy leads to the same result in Sicily in the baseline scenario;
- correlation among the initial investment and the NPV is linear and symmetrical to the change related to plant location. This result is obtained assuming that the costs of plant construction or financing of a region are the same as another. Hypothesis that may seem far from reality due to several factors including the multiplicity of suppliers of plants, the level of maturity of the sector that is not the same in all regions, the various technical features that can have a photovoltaic system, the multiplicity credit institutions. In fact, for small and medium size plants, the hypothesis is correct for several reasons: firstly, there are not literature references that provide guidance on the nonlinearity of the investment. This could be linked to some reasons, from lost found are defined for structure of power and have constant values, this led to not exploit the potential benefits of economies of scale for at least the size of the plant considered. In addition, the estimated unit cost of investment provided by the National Electric Board (ENEL), appears to be constant throughout the national scale [19]. To proceed with the introduction of different costs at provincial and regional level, there is the risk to introduce an higher level of subjectivity in the analysis. The impact that these costs can have on the final result, is taken under examination with the sensitivity analysis. The linearity of the result is connected at NPV definition which is determined by the product of the unit cost of investment for the power plant installed. In addition, maintenance costs and insurance are proportional to that value. A positive variation of 16% of the initial investment in Sicily yield the same result in the baseline scenario in Lombardy, a positive variation of 16% of the same variable in Lombardy leads to the same result in Sicily in the baseline scenario.
- Irrespective of plant location, with the variation of supply of electricity will have variations in NPV between the two variables,

Table 6
Percentage change in critical variables—Sicily region.

Feed in Tariff benefits			Initial Investment			PV module fabrication			Electric energy required		
$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$
Pessimistic scenario											
−25%	1.014	−61%	25%	839	−67%	−25%	774	−70%	−25%	1.668	−35%
−20%	1.325	−48%	20%	1.185	−54%	−20%	1.207	−53%	−20%	1.848	−28%
−15%	1.636	−36%	15%	1.531	−40%	−15%	1.595	−38%	−15%	2.028	−21%
−10%	1.947	−24%	10%	1.877	−27%	−10%	1.947	−24%	−10%	2.208	−14%
−5%	2.258	−12%	5%	2.223	−13%	−5%	2.270	−12%	−5%	2.389	−7%
Optimistic scenario											
5%	2.880	12%	−5%	2.915	13%	5%	2.856	11%	5%	2.737	7%
10%	3.190	24%	−10%	3.261	27%	10%	3.143	22%	10%	2.886	12%
15%	3.501	36%	−15%	3.607	40%	15%	3.430	34%	15%	3.014	17%
20%	3.812	48%	−20%	3.953	54%	20%	3.717	45%	20%	3.119	21%
25%	4.123	60%	−25%	4.299	67%	25%	4.005	56%	25%	3.203	25%

Table 7
Percentage change in critical variables—Lombardy region.

Feed in Tariff benefits			Initial Investment			PV module fabrication			Electric energy required		
$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$	$\Delta V\%$	x_i	$(x_i - x^*)/x^*$
Pessimistic scenario											
−25%	127	−91%	25%	−247	−117%	−25%	−458	−131%	−25%	721	−51%
−20%	398	−73%	20%	99	−93%	−20%	−37	−102%	−20%	901	−39%
−15%	670	−55%	15%	445	−70%	−15%	384	−74%	−15%	1.080	−27%
−10%	941	−37%	10%	791	−47%	−10%	788	−47%	−10%	1.239	−16%
−5%	1.212	−18%	5%	1.137	−23%	−5%	1.152	−22%	−5%	1.374	−7%
Optimistic scenario											
5%	1.754	18%	−5%	1.829	23%	5%	1.788	21%	5%	1.566	6%
10%	2.026	37%	−10%	2.175	47%	10%	2.070	40%	10%	1.621	9%
15%	2.297	55%	−15%	2.521	70%	15%	2.333	57%	15%	1.646	11%
20%	2.568	73%	−20%	2.867	93%	20%	2.581	74%	20%	1.648	11%
25%	2.839	91%	−25%	3.213	117%	25%	2.820	90%	25%	1.648	11%

however, there is no a linear and symmetrical link, this result stems from the fact that a variation of energy supply also involves a change in the distribution of quotas between the electricity produced for home consumption and the energy produced and available for sale. If there will be a reduction of energy, this reduction did not fall proportionately between the portion for self-consumption and for the share sale, the consumer will tend to meet in the first place its energy needs, therefore reducing the energy would be to impact on the total amount of energy available for sale. Only when the share of energy for the sale takes the value zero would be the reduction of the share of energy consumption. This aspect manifests its more than proportional effects in the NPV, for example, in the pessimistic scenario (that is associated with a reduction in supply energy) there is a reduction in the amount of energy sold to the manager (for which a unit price of €0.018 €/kWh is received) at the same the satisfy the energy demand requires that it is purchased at a price higher by 43% compared to the selling price (0.18 €/kWh). The resulting negative impact on the NPV are estimated to be partially offset by the main source of benefit represented by the energy incentives into FiT (€0.403 €/kWh) In the optimistic scenarios, instead, the situation is not homogeneous: in Sicily, unlike England, is has a linear relationship between two quantities.

- change in demand for electricity has not directly correlated at the NPV. Even this variable, like the former affects the percentage of electricity produced for self consumption and energy to be sold to the network manager. In addition, must be stressed that in the pessimistic scenarios there is an almost linear relationship (see for example the case of Sicily); this linearity comes from the relationship between demanded and saved energy, reducing the required amount decreases proportionately the amount of energy saved and disappears, if there is, the quantity sold to the manager. In the optimistic scenarios an increase in demand for energy higher than that of electricity generated, do not cause any change in the value of the NPV, in areas where the average annual insolation is higher and therefore where the risk decreases was an increase almost linearly.
- If there is a decrease of 30% of energy demanded in Sicily, there would still be the same result for the baseline scenario in Lombardy and in no case a positive variation of the same variable in Lombardy would store the same result in the scenario of Sicily basis.
- It should be noted that while in Sicily in any subscenarios there are negative values of the index, in Lombardy in subscenarios 3 (increase of 25% of the initial investment and a decrease of 20% and 25% of electricity of supply) NPV takes a negative value.
- The results are influenced by plant size, it is therefore necessary to proceed at a sensitivity that allows to give strength to the results obtained.

3.2. Switching values of critical variables

This section analyzes the switching values. The switching value of a variable is that value that would have to occur in order for the NPV of the project to become zero, or more generally, for the outcome of the project to fall below the minimum level of acceptability. The use of switching values in sensitivity analysis allows appraisers to make some judgments on the riskiness of the project and the opportunity of undertaking risk-preventing actions. This analysis is related at the critical variables of the project [20].

For such a scope, it is to build a consistent set of underlying assumptions, such that the amount of induced effects can justify the expense for the investment. The assumptions used in the switching scenario should be compared with the economic-statistical values of the area covered by the investment, to check their acceptability. This analysis provides the amount that the exogenous variables must assume so that the investment is economically justifiable [21].

Table 8
Regional reversal value of critical variables.

	Decrease of *FiT*	Increase of I_0	Decrease of E_{OUTPUT}	Decrease of Q_{el}
Piedmont	−28%	22%	−22%	−56%
Aosta Valley	−20%	15%	−14%	−53%
Lombardy	−27%	21%	−21%	−56%
Trentino	−22%	17%	−16%	−54%
Veneto	−28%	22%	−22%	−56%
Friuli	−24%	19%	−18%	−55%
Liguria	−31%	25%	−25%	−57%
Emilia R.	−31%	25%	−25%	−57%
Tuscany	−32%	26%	−26%	−58%
Umbria	−33%	27%	−28%	−58%
Marche	−32%	27%	−27%	−58%
Lazio	−35%	30%	−31%	−59%
Abruzzo	−33%	28%	−28%	−59%
Molise	−35%	29%	−30%	−59%
Campania	−36%	31%	−32%	−61%
Apulia	−37%	32%	−34%	−62%
Basilicata	−36%	31%	−32%	−61%
Calabria	−39%	34%	−36%	−66%
Sicily	−41%	37%	−40%	−71%
Sardinia	−39%	34%	−36%	−66%
Average	−32%	27%	−27%	−59%

The results obtained, on national average, define that the investment is not justified (because the NPV is negative) under the following assumptions (Table 8):

- Feed in Tariff (*FiT*) reduction of 32%.
- Initial investment cost (I_0) increase of 27%.
- Annual energy output of the system (E_{OUTPUT}) reduction of 27%.
- Electric energy required by consumers (Q_{el}) reduction of 59%.

Each region has certainly a different contribution to the definition of average value, the analysis of regional data puts emphasis on certain aspects.

With reference to the FiT benefits, in Sicily the NPV has a positive value up to a reduction of almost 41%, in Sardinia and Calabria would be possible to push the reduction of this variable up to 39%. The regions that show a particularly high sensitivity to this variable are Aosta Valley and Trentino, that with a reduction of 20% and 22% reported a negative NPV.

For the increase of I_0 are always Sicily, Sardinia and Calabria to be the most virtuous, and these regions have a large degree of variation than the national average. On average, an increase of 27% of this variable would lead to a NPV reduction until it reaches the value zero, but, for Sicily the increase can reach 37% and for Sardinia and Calabria 34%.

The results obtained by assuming a decrease in supply and/or energy demand confirm this trend. In general, according to the profitability of the PV system, it is possible to split the Italian territory into two groups: regions with high rates of return generated by the plant and unproductive regions. Considering the average switching values of each variable, in terms of absolute value, in some regions it is possible to record a value significantly worse than the average value before the NPV becomes zero.

3.3. Relationship among NPV and opportunity cost of capital

The opportunity cost of capital (r) depends on the risk of the project and it is a measure of an alternative investment with the same risk of the project under analysis. An its variation strongly influences the profitability of an investment. The European Commission [15] suggests a value of 5% in real terms. However, values

Table 9
Net Present Value and opportunity cost of capital.

	$r=3\%$		$r=4\%$		$r=6\%$		$r=7\%$	
	x_i	$(x_i-x^*)/x^*$	x_i	$(x_i-x^*)/x^*$	x_i	$(x_i-x^*)/x^*$	x_i	$(x_i-x^*)/x^*$
Piedmont	2241	47%	1852	21%	1250	−18%	1016	−33%
Aosta Valley	1656	58%	1324	27%	814	−22%	619	−41%
Lombardy	2190	48%	1806	22%	1211	−18%	982	−34%
Trentino	1785	55%	1441	25%	910	−21%	707	−39%
Veneto	2258	47%	1868	21%	1262	−18%	1028	−33%
Friuli	1948	51%	1588	23%	1032	−20%	818	−36%
Liguria	2494	44%	2080	20%	1437	−17%	1188	−31%
Emilia R.	2479	44%	2066	20%	1426	−17%	1177	−32%
Tuscany	2600	43%	2176	20%	1516	−17%	1259	−31%
Umbria	2688	42%	2256	19%	1582	−16%	1319	−30%
Marche	2600	42%	2176	18%	1516	−17%	1259	−31%
Lazio	2881	41%	2430	19%	1726	−16%	1451	−29%
Abruzzo	2718	42%	2282	19%	1603	−16%	1339	−30%
Molise	2844	41%	2396	19%	1698	−16%	1426	−29%
Campania	2989	40%	2527	18%	1806	−15%	1525	−29%
Apulia	3082	39%	2611	18%	1876	−15%	1589	−28%
Basilicata	2997	40%	2534	18%	1812	−15%	1531	−29%
Calabria	3252	38%	2766	17%	2005	−15%	1708	−27%
Sicily	3509	37%	3000	17%	2202	−14%	1889	−26%
Sardinia	3255	38%	2768	17%	2007	−15%	1710	−27%
Average	2623	44%	2197	20%	1535	−17%	1277	−31%

that differ by this parameter can be justified in relation to the macroeconomic conditions of the Member State, the nature of the investor (the injection of private capital tends to increase the discount rate) and the sector under analysis.

The parameter variation of 1% is made in two optimistic scenarios ($r=3\%$; $r=4\%$) and in two pessimistic ($r=6\%$; $r=7\%$). The results are expected, because this parameter (at the denominator of the ratio of discounting) has an inverse relationship to the final result (Table 9):

- If $r=3\%$ the national average value is 2.623 €; if $r=4\%$ is 2.197 €; if $r=5\%$ is 1.839 €; if $r=6\%$ is 1.535 € and if $r=7\%$ is 1.277 €. So for lower value of r, the NPV increases more than proportionally;
- changes in the NPV are contained in the regions where the annual average insolation value is higher;
- in the 5 scenarios analyzed, the percentage variation of NPV is 75%.

3.4. Relationship among NPV and project lifetime

Besides the opportunity cost of capital plays a critical and fundamental role, in the calculation of NPV, the project lifetime, which is a function of the nature of the investment. This time period has to cover the long-term effects of the variables that characterize the cash flows.

The European Commission proposes for the energy sector, a reference time period between 15 and 25 years [15]. Since the FiT benefits last for 20 years, chosen a lower area develops the investment is not consistent with what happens in reality. It is clear that this is a incorrect chosen, the minimum value to be taken for photovoltaic systems is therefore 20 years, this is also in line with what is dictated by the cost–benefit analysis guide in which the average value of the proposed range coincides with the value the years in which it is possible to receive government grants.

For projects with a time duration greater than 20 years, occurs that despite the absence of FiT benefits, the share of annual revenue is greater than the annual operating costs and therefore tends to increase the NPV. The scenario with a time duration of 20 years is therefore to have a pessimistic nature than that in 25 years [22].

In the next section, an analysis on the obtained results is presented, the Italian territory is investigated for identify the regions where investments in photovoltaic have a higher profitability.

4. Finding analysis

In the present work has evaluated the installation of photovoltaic systems in all Italian regions, sized to an extent to meet the needs of consumers and reduce CO_2 emissions, the estimated NPV allowed to quantify the efficiency of photovoltaic systems by putting the light on the variability of return linked to the plant location on national country. In some regions favorable geographical position can more than offset the deterioration of the variables that determine the performance of the project, [23]. In particular, the sensitivity analysis has shown that in some regions would have to register a general deterioration of all the four critical variables (FiT, I_0, E_{OUTPUT}, Q_{el}), so to have a cancellation of return linked to the investment in terms of NPV.

In Table 9 were identified values of the four critical variables overthrow regional and national average. Compared to the national level is possible to identify some regions that have a switching value above average, particularly in Sicily, Sardinia, Calabria, Apulia, Basilicata, Campania, Lazio, Molise, Abruzzo and Umbria. These regions can better tolerate adverse changes in each of the four variables of the project.

The values in Fig. 4 shown, for each variable, the possible deviation from the national average, before that NPV moved from a positive value to a zero. If, for example, for an average reduction of 32.10% of incentive the investment becomes economically not appropriate, in Sicily, the variation margin is wider than 9.22% (with a total deviation which can thus oscillate up to 41%). It is interesting to note that for these regions "virtuous" is recorded the same trend for each of the four variables. Only exception is from Abruzzo and Umbria where, only referring to the change in energy demand, the figure is slightly lower than the national average.

Not only in these regions there is a greater capability to withstand negative changes in the critical variables, but also the magnitude of these changes always came around the same values: the extremes of this classification there are always Sicily (with the most important deviations from the average value) and Umbria (with specific values very close to the national average).

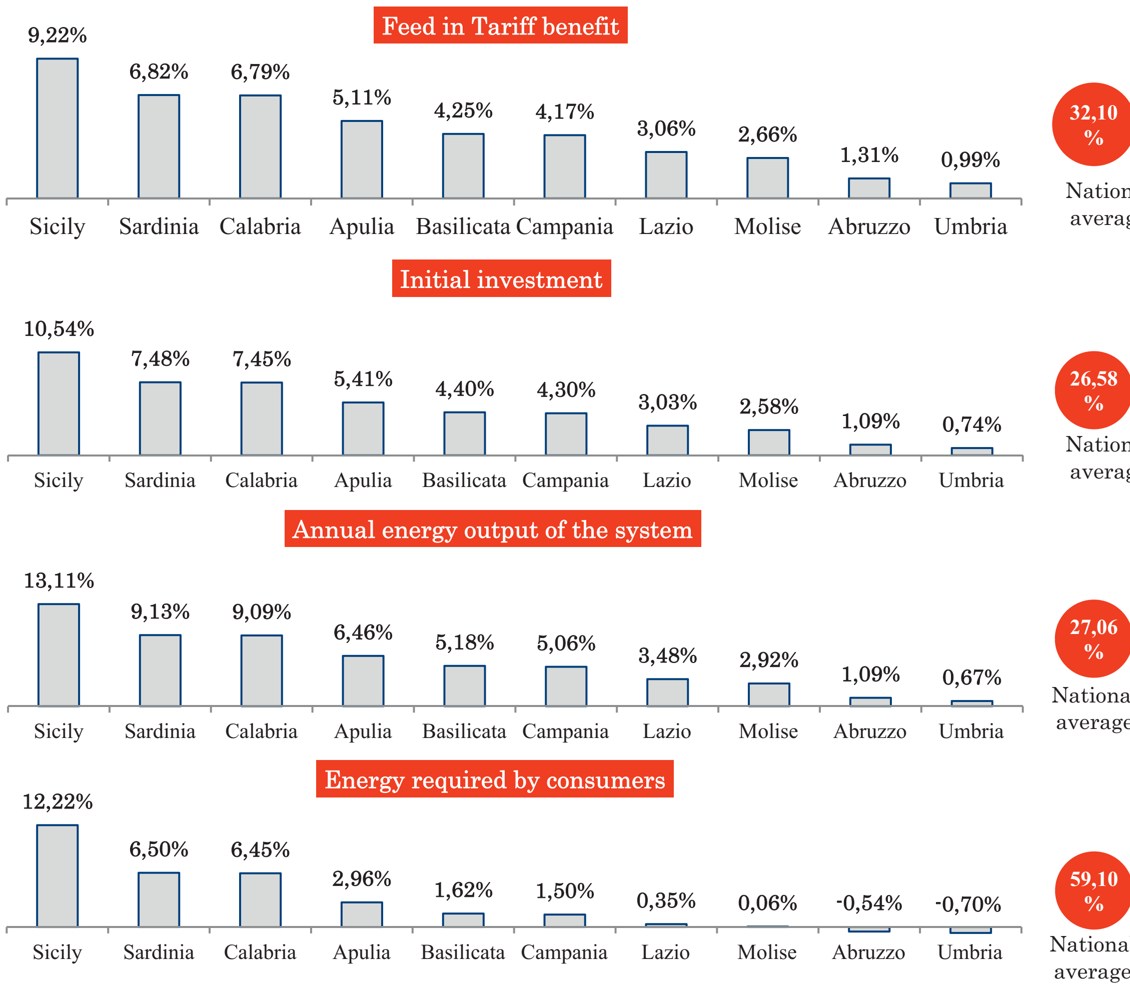


Fig. 4. Virtuous regions: deviation of critical values from national average.

For the remaining regions, however, would be sufficient a downgrading of the variables also below the average value to record a negative NPV of the project. These regions are the Marches, Tuscany, Liguria, Emilia Romagna, Veneto, Piedmont, Lombardy, Friuli, Trentino, Aosta Valley. In this case, arranging the regions from the most "virtuous", there is the same ordering for all the variables. The deviations from the average value of these variables are reported in Fig. 5. Marche is the region more able to support a worst change, while in Aosta Valley, the framework is much more critical. If on average in Italy it is necessary that the initial investment increases of 26.58% to discourage investment in the photovoltaic sector in Aosta Valley the change in this variable is 15.13%, with a difference from the average value of 11.45%.

Even for these regions (which have values less than the switching average value) there is the same ordering for each of the four variables. The only exception is the Marche and Tuscany where the change in the incentive rate is slightly higher than the national average.

The analysis highlights the presence of two groups of Italian regions, the distinction can be made considering the capacity to support or not a general worsening of conditions in which the investment is implemented. The analysis of results also highlights the relevance of the geographical location of the plant, the regions that can better tolerated variations of the general framework are all located in southern Italy. In the next section the focus is on this aspect.

5. PV production localization relevance

The sensitivity analysis carried out previously highlighted the relevance of plant location in Italy. If this aspect is generally observed in every nation, is even more pronounced in Italy for the particular conformation of the territory. For this reason there is a wide variability in the amount of solar energy that reaches Earth's surface and that can be usefully "collection" by a photovoltaic device, the amount of energy depends, in fact, from place irradiation [24].

The radiation is, in fact, the amount of solar energy incident on a unit surface area at a given time period, typically one day, expressed in kWh/(m^2 day).

The instantaneous value of the solar radiation incident upon the surface is instead called radiance (kW/m^2). The radiation is influenced by local climatic conditions (clouds, haze, etc.) and depends on the latitude of the place, the shorter the distance from the equator, the greater the radiation [25].

In Italy, the average annual radiation ranges from 3.6 kWh/(m^2 day) of the Pianura Padana to 4.7 kWh/(m^2 day) of the center South and 5.4 kWh/(m^2 day) of Sicily. This confirms that the regions suitable for development of photovoltaic are the southern and island regions. In northern regions, however, it has recorded the sustainability of the investment, in fact, photovoltaic systems can be installed also in less sunny place for the ability of these systems to take advantage from diffuse radiation.

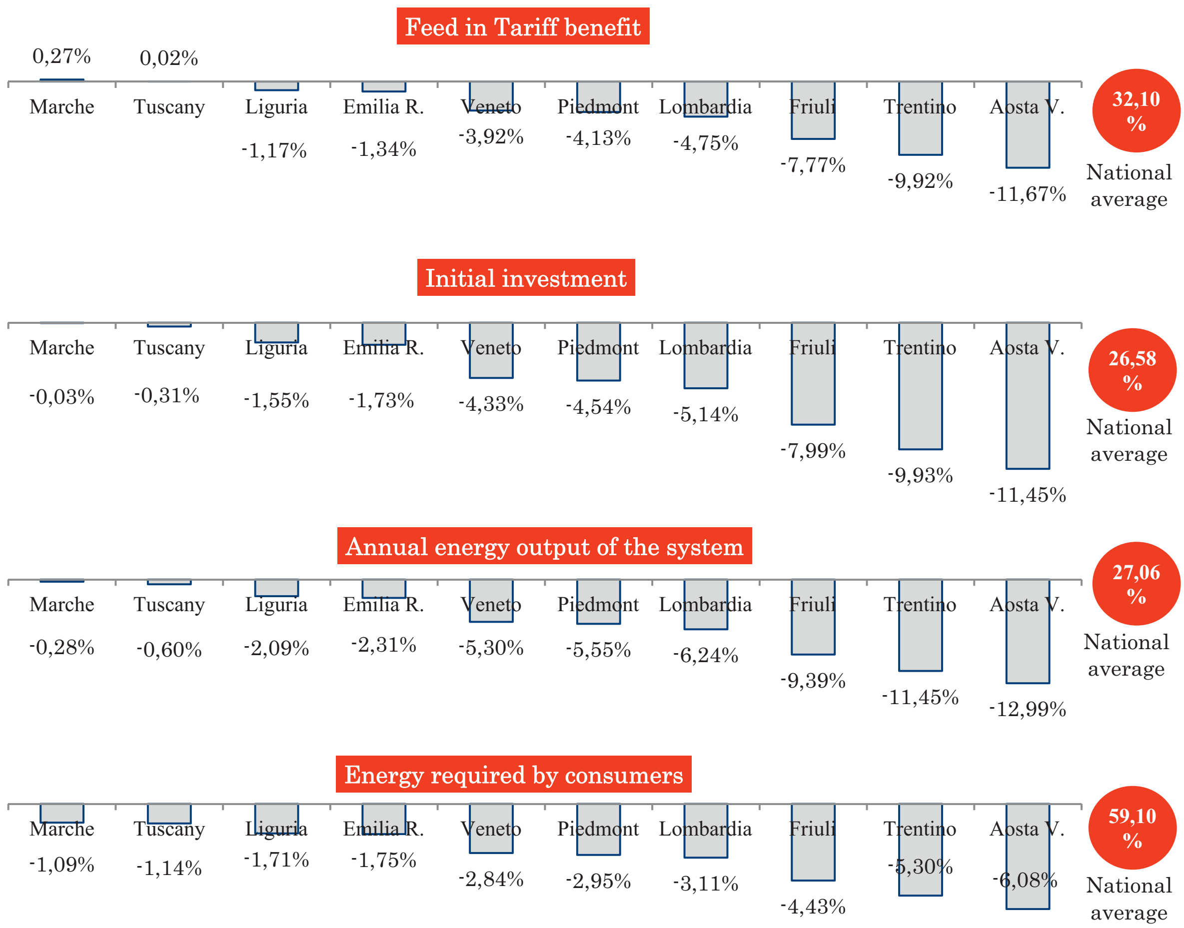


Fig. 5. Bad regions: deviation of critical values from national average.

In the previous section there were two groups of regions classified according to the profitability of investments in photovoltaic. Since the data were normalized, has been possible to make a comparison between projects located in different places in the Italy, [26]. In this paragraph is analyzed how solar radiation affects the return of such investments. For this purpose it is necessary to sort the regions according to radiation registered and compared this data with that relating to the performance.

To get the value of the radiation regional was considered the data of the radiation relative to each province, where the average value of the radiation region has been set equal to the average value of the data recorded in each province. The regions showing a strong correlation between the irradiation and as the return on investment. Considering the top ten regions with the highest radiation, it has to note that these coincide with the ten regions in which the switching values are almost always have higher than the

Italian annual irradiation

Regions with higher irradiation		Regions with lower irradiation	
Sicily	1632,89	Marche	1443,20
Sardinia	1574,38	Tuscany	1438,80
Calabria	1573,80	Liguria	1418,75
Apulia	1536,50	Emilia R.	1415,88
Basilicata	1518,50	Veneto	1375,71
Campania	1516,80	Piedmont	1372,63
Lazio	1494,60	Lombardy	1363,58
Molise	1487,00	Friuli	1322,25
Abruzzo	1461,75	Trentino	1295,50
Umbria	1456,00	Aosta Valley	1275,00

Fig. 6. The borderline of Italian virtuous regions.

Table 10
Scenario variable definition.

Optimistic scenario	T.I.	I.I.	O.E.	D.E.	Pessimistic scenario	T.I.	I.I.	O.E.	D.E.
O5	+25%	−25%	+25%	+25%	P1	−5%	5%	−5%	−5%
O4	+20%	−20%	+20%	+20%	P2	−10%	10%	−10%	−10%
O3	+15%	−15%	+15%	+15%	P3	−15%	15%	−15%	−15%
O2	+10%	−10%	+10%	+10%	P4	−20%	20%	−20%	−20%
O1	+5%	−5%	+5%	+5%	P5	−25%	25%	−25%	−25%

average value (Fig. 6). Moreover, the ordering of the two groups of regions coincides perfectly, in fact, in the normalized analysis the only parameter that ranges is the average annual insolation.

After the analysis of the financial indicator with respect to the single critical variables, in the next section is finalized to evaluate the impact that the simultaneous variation of all critical variables have on Net Present Value.

6. Scenario analysis

The method of the scenario analysis supplements and integrates simulation techniques since it leads to choose, among the various future outcomes of interest and in a flexible way, the trajectory which comes from the scenario that best corresponds to the set of events which are happening [27].

Correct use of this technique suggests that:

- the scenarios correspond to several degrees of trends of the economic state of interest;
- the scenarios are defined by a small number of variables with respect to the number of simulated outputs;
- the selected independent variables, through their possible combinations, must be representative in sufficient detail of the various economic situations that may happen during the chosen forecast period.

The estimation of future realizations of variables of interest on the basis of different scenarios leads to a better understanding of the implications between the simulated outputs and the scenario variables.

In general, every scenario has its own probability to occur which reflects the degree of likelihood that the related hypotheses may happen. The user can choose to utilize the forecasts related to the scenario more probable and/or more coherent with his perception of the behavior of the economy.

To define the optimistic or pessimistic scenarios, it has to choose for each critical variable extreme values than those defined by the probability distribution.

In this paper not only two scenarios are considered, characterized respectively by the minimum and maximum values of the variables, but five scenarios pessimistic and five optimistic are taken under analysis (Table 10). The characteristic of each scenario is that the percentage differences of the variables compared to the baseline scenario are identical. This means that in the same scenario may occur both problematic outcomes of some critical variables than less problematic outcomes of other critical variables.

This is clearly a bug, which finds solutions in risk analysis conducted in the next step. The choice made has, however, allowed to have a more complete overview on the results of the viability of the large number of scenarios examined.

Analyses were performed for all regions (Table 11) and emerges as starting from pessimistic scenario P3 for all regions have a negative NPV. In fact, already from P2 scenario are recorded negative NPV, with the exception of Sicily, Sardinia, Calabria, Apulia, Basilicata and Campania.

The percentage changes are higher in the optimistic scenario than pessimistic and like the previous results there is a dividing line between Umbria (the last of the regions economically virtuous) and Marche (the first of the economically less virtuous regions).

After performing the sensitivity and scenario analysis, in the next section we proceed to present the results of risk analysis, which completes the set of information necessary to determine the profitability of investments in different Italian regions.

Table 11
Scenario analysis with regional detail—NPV.

	P5	P4	P3	P2	P1	O1	O2	O3	O4	O5
Sicily	−2664	−1679	−664	382	1460	3708	4879	6081	7314	8578
Sardinia	−2792	−1823	−824	206	1266	3477	4628	5809	7021	8263
Calabria	−2794	−1825	−825	204	1264	3475	4626	5807	7018	8260
Apulia	−2880	−1921	−932	87	1135	3321	4459	5626	6823	8050
Basilicata	−2922	−1968	−984	29	1071	3245	4376	5537	6727	7947
Campania	−2926	−1973	−989	23	1065	3238	4369	5528	6718	7937
Lazio	−2980	−2033	−1056	−50	985	3142	4264	5416	6597	7806
Molise	−2999	−2054	−1079	−76	956	3109	4228	5377	6554	7761
Abruzzo	−3063	−2125	−1158	−162	862	2996	4106	5245	6412	7608
Umbria	−3078	−2141	−1176	−182	840	2970	4078	5214	6379	7573
Marche	−3111	−2178	−1217	−227	791	2911	4014	5146	6305	7493
Tuscany	−3122	−2191	−1231	−243	773	2891	3992	5122	6280	7466
Liguria	−3175	−2250	−1296	−315	694	2797	3891	5012	6161	7339
Emilia R.	−3183	−2259	−1306	−326	683	2783	3876	4996	6144	7320
Veneto	−3294	−2382	−1443	−476	518	2588	3664	4767	5898	7056
Piedmont	−3303	−2392	−1453	−488	505	2573	3647	4749	5879	7035
Lombardy	−3329	−2421	−1485	−523	467	2527	3598	4696	5821	6973
Friuli	−3451	−2557	−1636	−688	286	2313	3366	4446	5552	6684
Trentino	−3534	−2649	−1738	−800	163	2168	3209	4276	5369	6488
Aosta Valley	−3600	−2722	−1818	−889	66	2053	3085	4142	5225	6334
Average	−3110	−2177	−1216	−226	793	2914	4018	5150	6310	7499
Variation%	−269%	−218%	−166%	−112%	−57%	58%	118%	180%	243%	308%

Table 12
Probability distributions—alternative scenarios.

Scenario	Distribution of critical variables
A	Rectangular
B	Normal
C	Triangular

7. Risk analysis

The evaluation of the effects that variables percentage changes have on reference indicator of a project, does not provide information about the likelihood that such phenomena occur. To get an indication on this aspect is necessary to conduct a risk analysis. This analysis requires the estimation of a probability distribution of financial and economic indicators, such an estimate is done by assigning the appropriate probability distributions to critical variables, and this allows to provide interesting statistics on the performance indicators of the project [28].

The definition of the probability distribution to assign to critical variables can be difficult to solve, the difficulty is extended by the possible absence of historical data on similar projects. In the absence of experimental data, it is possible to use the typical distribution shown in literature [29]:

- triangular distribution is used when it is known that there is a better probability of finding values close to the mean value than further away from it, and one is more comfortable estimating the width of the variation by estimating "hard" limits rather than a certain number of standard deviations;
- normal distribution, is used when there is a better probability of finding values closer to the mean value than further away from it, and one is comfortable in estimating the width of the variation by estimating a certain number of standard deviation;
- rectangular distribution is used when the variation limits are known, but there is no information about the distribution between these limits.

Four scenarios are analyzed, each characterized by the assumption that the probability distribution is the same for the critical variables (Table 12). The FiT benefit is constant therefore is not be subject to the probability distribution. The incentive structure, however, varies depending on the architecture of the plants and, from 2011, also from the monthly period (rather than yearly) in which the investment is made, it is therefore necessary to identify the type of distribution that best describes the variability of values.

The main statistical information derived from a risk analysis are: expected values (Mean), standard deviation (stddev), minimum (Min), maximum (max), cumulative probability of positive

Table 14
Probability value.

Regions	Scenario A		Scenario B		Scenario C	
	p_{POS}	$p_{CUM} > p_{RIF}$	p_{POS}	$p_{CUM} > p_{RIF}$	p_{POS}	$p_{CUM} > p_{RIF}$
Sicily	100%	91%	89%	62%	100%	96%
Sardinia	100%	84%	89%	59%	100%	88%
Calabria	100%	84%	88%	58%	100%	88%
Apulia	100%	74%	86%	55%	100%	77%
Basilicata	100%	68%	86%	54%	100%	75%
Campania	100%	67%	86%	53%	100%	74%
Lazio	100%	63%	86%	52%	100%	69%
Molise	100%	62%	85%	50%	100%	66%
Abruzzo	100%	52%	84%	47%	100%	56%
Umbria	100%	52%	84%	47%	100%	51%
Marche	100%	47%	84%	44%	100%	49%
Tuscany	100%	43%	84%	44%	100%	46%
Liguria	100%	37%	83%	43%	100%	40%
Emilia R.	100%	37%	83%	43%	100%	39%
Veneto	100%	25%	81%	41%	100%	23%
Piedmont	100%	24%	79%	40%	100%	20%
Lombardy	100%	22%	79%	39%	100%	18%
Friuli	100%	12%	76%	33%	100%	6%
Trentino	99%	9%	73%	29%	100%	2%
Aosta Valley	98%	6%	71%	29%	100%	1%

Table 15
Sizing scenarios.

Scenario	Power PV panel (kWp)	Energy required in 1 y (kWh)
H	5	5.000
I	10	10.000
J	15	15.000
K	20	20.000

Table 13
Descriptive statistical– Net Present Value.

Regions	Scenario A				Scenario B				Scenario C			
	Min	Mean	Max	Stddev	Min	Mean	Max	Stddev	Min	Mean	Max	Stddev
Sicily	1090	2561	4030	587	−2908	2513	8099	2040	1454	2564	3688	439
Sardinia	889	2342	3786	578	−3078	2277	7426	2004	1314	2350	3434	433
Calabria	864	2344	3769	576	−3092	2273	7751	2000	1296	2348	3419	430
Apulia	773	2199	3598	570	−3146	2038	7243	1974	1157	2206	3273	427
Basilicata	714	2122	3564	563	−3197	2035	7359	1967	1106	2135	3193	421
Campania	679	2128	3605	565	−3233	1794	7005	1962	1075	2129	3214	424
Lazio	657	2033	3493	561	−3244	1938	7185	1938	1027	2041	3079	418
Molise	632	2002	3470	555	−3258	2117	7497	1908	973	2010	3078	419
Abruzzo	505	1898	3246	552	−3281	1908	7095	1925	908	1906	2936	412
Umbria	467	1820	3251	555	−3350	1772	6837	1920	841	1882	2897	412
Marche	463	1874	3234	548	−3386	1714	6791	1918	834	1828	2873	407
Tuscany	400	1801	3214	544	−3389	1695	7124	1928	816	1809	2844	410
Liguria	392	1714	3099	543	−3404	1383	6401	1897	738	1723	2740	404
Emilia R.	362	1702	3076	541	−3427	1600	6925	1898	716	1710	2695	404
Veneto	232	1521	2887	530	−3444	1584	6489	1874	557	1530	2523	398
Piedmont	218	1506	2771	524	−3547	1402	6335	1872	532	1516	2475	395
Lombardy	137	1465	2833	535	−3627	1139	5944	1856	512	1474	2450	394
Friuli	43	1266	2531	521	−3637	1340	6252	1835	322	1277	2231	387
Trentino	−86	1132	2390	512	−3714	1013	5697	1809	222	1142	2108	387
Aosta Valley	−171	1026	2225	514	−3812	898	5450	1780	81	1036	1962	380
Average	824	1831	2855	410	−3359	1722	6845	1915	463	1823	3204	549

Table 16
Net Present Value for several system sizing.

	H		I		J		K	
	x_i	$(x_i - x^*)/x^*$	x_i	$(x_i - x^*)/x^*$	x_i	$(x_i - x^*)/x^*$	x_i	$(x_i - x^*)/x^*$
Sicily	12,843	400%	25,686	900%	38,530	1400%	51,373	1900%
Sardinia	11,784	359%	23,567	817%	35,351	1276%	47,134	1735%
Calabria	11,773	358%	23,546	817%	35,319	1275%	47,092	1733%
Apulia	11,067	331%	22,133	762%	33,200	1193%	44,266	1623%
Basilicata	10,718	317%	21,436	735%	32,154	1152%	42,872	1569%
Campania	10,685	316%	21,369	732%	32,054	1148%	42,739	1564%
Lazio	10,244	299%	20,487	698%	30,731	1096%	40,975	1495%
Molise	10,090	293%	20,180	686%	30,270	1078%	40,360	1471%
Abruzzo	9572	273%	19,145	645%	28,717	1018%	38,290	1391%
Umbria	9452	268%	18,904	636%	28,356	1004%	37,808	1372%
Marche	9184	258%	18,368	615%	27,552	973%	36,737	1330%
Tuscany	9090	254%	18,180	608%	27,270	962%	36,360	1316%
Liguria	8659	237%	17,318	574%	25,977	911%	34,636	1248%
Emilia R.	8596	235%	17,192	569%	25,787	904%	34,383	1239%
Veneto	7697	200%	15,393	499%	23,090	799%	30,787	1099%
Piedmont	7626	197%	15,253	494%	22,879	791%	30,506	1088%
Lombardy	7416	189%	14,833	477%	22,249	766%	29,665	1055%
Friuli	6430	150%	12,861	401%	19,291	651%	25,722	901%
Trentino	5762	124%	11,524	349%	17,286	573%	23,047	797%
Aosta Valley	5234	104%	10,467	308%	15,701	511%	20,935	715%
Average	9196	258%	18,392	616%	27,588	974%	36,784	1332%

NPV (p_{POS}) and cumulative probability of NPV more than a reference value ($p_{CUM} > p_{RIF}$), the reference value chosen is 1.839 €, or the value of the NPV national average in the baseline scenario (Tables 13 and 14).

Analyzing the results, it has to highlight that:

- regardless of the probability distribution, in accordance with previous results, the regions where there are more and less efficient values are, respectively, Sicily and Aosta Valley;
- the range of NPV values obtained when critical variables have a normal distribution is much wider than that with the rectangular and triangular distribution. The density values in the tails is a characteristic of the normal distribution;
- in the scenario C, the NPV is always positive, while in scenario A, the financial indicator has a negative sign only in Trentino (1%) and Aosta Valley (2%). Finally, in scenario B the NPV is negative in all regions: the probability that it is in Sicily is 11% and 29% of the Aosta Valley;
- the range of probability that the NPV is greater than the reference value is much higher in scenarios A and C compared to scenario B.

The results showed as also in the normalized case the investment will produce profits for the investor.

In the next section the paper is completed by considering different sizes of the plants in order to assess the relationship between the dimensional parameter of the project and the results obtained in the preceding paragraphs.

8. Relationship NPV–PV system size

The sizing of a photovoltaic system depends from: power consumption demands, economic availability of investor, area available for PV modules and by priority project [30].

In this step the objective of the work is to evaluate the impact of plant size on the profitability of investment in each region. Under the same numerical inputs, have identified 4 scenarios in which changes only the two macro variables related to: demand and supply of electricity. The first variable is related to the number of photovoltaic modules, the second the value of the energy required by the user in the first year of life of the system (Table 15).

In this risk analysis the NPV is estimated in each scenario, and it has assessed as changes compared to the baseline scenario (Table 16):

- NPV growth in each region is linear if the change in demand and supply of electricity are linear;
- the growth rate of the NPV for every 5 kWp of power output and 5.000 kWh of energy required is equal to 500% if the plant is located in Sicily, to 204% if it is located in the Aosta Valley and 358% considering the national average.

The realization of larger plants is certainly more profitable, but as mentioned previously, the choice of an investment depends on the initial amount available (5 kWp installation requires an initial outlay of about € 33,000) and the availability space where to install the solar panels (5 kWp installation requires a space of about 40 m^2).

9. Conclusions

Today photovoltaic solar energy represents one of the most secure investment products on the market, its return rate and its high interest constitute an investment option that has taken the sector to strong upward growth in recent years. Tax rebates and the refund of NPV also allow part of the economic contribution invested to be recovered in a very reasonable period, which can also benefit from soft loans and other fiscal benefits that make solar energy a highly profitable product in economic and social terms. A reflection of all this is the appearance of different investment funds and specific credits for this type of activity, which have noticeably contributed to the advance of this kind of alternative energy.

Considering the national average, has been defined under what conditions investments in photovoltaic are to be not economically opportune. In particular, were first identified the critical variables of these investments, then were identified the switching values of these variables. Moreover, according to the profitability of the PV system, Italy has been divided into two groups: regions with high rates of return generated by the plant and unproductive regions.

Variations in the benchmark are smaller in regions where the annual average insolation value is higher and it is interesting to

note that for each region there is the same tendency for each of the critical variables.

The scenario analysis has confirmed the presence of a line on Italian territory, the risk analysis has further confirmed the results obtained previously and has shown that under the assumption that the variables assume a normal distribution (and non-triangular or rectangular) the range of values of the NPV is more wide.

PV systems certainly have future in Italy, but there is a need for detailed analysis of the existing related legislation and of possible improvements. Removing the normalization limit, simplification of the procedure and additional support from the state are key factors for higher penetration of PV. Larger systems do mean a larger outlay, but generally speaking they are better value for money, as there are lower installation costs and much higher returns and savings per watt created. Smaller systems take as long to return their investment (sometimes longer) and offer lower returns over all.

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